PlanetQuest

The Search for Another Earth

SCRIPT

Slide 1

The beginning image is a placeholder to be projected while guests are coming in. Presenters can use it for introductory remarks about this tale of one of our greatest quests.

[Be sure to use the "**Slide Show**" format in PowerPoint when you give this presentation. Several of the slides are animated, and the animations will not work in the normal "slide view."]

SCRIPT:

Of all the questions we can ask about the universe, perhaps none appeals more to us as human beings than the question: "Are there other planets in space similar to our own that contain living beings?" While we may be getting closer to finding an answer, the journey that has brought us this far is full of surprises.

WHAT'S ON THE SLIDE:

This artist's concept depicts an itsy bitsy planetary system -- so compact, in fact, that it's more like Jupiter and its moons than a star and its planets. Astronomers using data from NASA's Kepler mission and ground-based telescopes recently confirmed that the system, called KOI-961, hosts the three of the smallest exoplanets known so far to orbit a star other than our sun. An exoplanet is a planet that resides outside of our solar system.

Credit: *NASA/JPL-Caltech*

NOTE ON THE PRESENTATION SCRIPT:

The italicized portion of the script summarizes the text on the slide. If you want to give a faster version of the presentation, use mostly this text. The Extras are a suggestion of what you might want to say to add some more detail and lengthen the presentation or to answer common questions.

Slide 2

SCRIPT:

***As ancient humans began to explore more of our home planet, the night sky led them and also inspired questions. "*Where do we come from?" " Are we alone?"**

WHAT'S ON THE SLIDE:

An artist's conception of early people watching the sky wondering about other worlds.

Slide 3

SCRIPT:
The ancient Greeks called these moving lights "planetai" meaning "wandering stars." The word comes down to us today as "planets," and the names we use are the ones given to them by the Romans.

WHAT'S ON THE SLIDE:
Enhanced visualization of actual planet images. The relative sizes of the planets are not to scale, and neither are the distances.

EXTRAS:
The motions of the various planets against the starry background is due to the fact that each planet is traveling around our Sun in a different orbit and at a different speed (as is the Earth). Because the orbits of planets seen with the naked eye are all roughly in the same plane (the solar system is somewhat flat like a pancake), we see the planets travel through a narrow band, or zone, that encircles the sky.

Slide 4

SCRIPT:
Speculation about distant worlds is not new. Thousands of years ago, Greek philosophers imagined other worlds like ours.

Examples of early philosophical musings included the following from the Greek philosopher Epicurus, whose quote is shown here. And, in the 1st century BC, the Roman philosopher Lucretius reasoned, "In the universe, nothing is only one of its kind. In other regions, surely there must be other Earths, other men, and other beasts of burden."

WHAT'S ON THE SLIDE:
The fresco "La Scuola di Atene" (The School of Athens) was painted by Raphael (Raffaello Sanzio, 1483-1520) in the years 1509 -1511 and is located in the "Stanza della Segnatura" in the Vatican. The School of Athens was commissioned by Pope Julius II and the stanza della Segnatura was one of the rooms in which he lived and worked.

EXTRAS:
There are many other examples of early speculation about other worlds. In the 5th century BC, the Greek philosopher Metrodus of Chios wrote, "To consider the Earth the only populated world in space is as absurd as to think that in an entire field sown with seed, only one grain will grow." In 13th century China, the sage Teng Mu professed, "Outer space is like a kingdom and our Earth and sky are like no more than a single person in that kingdom." And in the 15th century, the Muslim astronomer Ulugh Beg noted that in the Koran it says, "Among (God's) signs is the creation of the heavens and the Earth, and the living creatures that He has spread in both of them." The notion of extraterrestrial life has been quite common across cultures and across the centuries. At times such notions were acceptable. At others, societies and cultures were not as tolerant.

Slide 5

SCRIPT:
As our understanding of the universe changed, the idea that there might be other worlds like ours was still in the minds of philosophers and scholars.
In the year 1584, the Italian monk, Giordano Bruno also expressed belief in the possibility of life on other worlds. For these and other heresies, the Church burned him at the stake
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WHAT'S ON THE SLIDE:
Early drawing of Giordano Bruno.

EXTRAS:
Giordano Bruno was born in 1548 and was executed in the year 1600 after a lengthy trial. He was a staunch supporter of the Copernicus Theory and believed that the universe was infinite. Excommunicated from the Calvinist Church, he moved to France in 1582 and became the royal lecturer for King Henry III. He escaped prosecution for his views twice before he was burned at the stake for his heretical teachings.

Slide 6

SCRIPT:
400 years ago, the budding technology of the time changed our view of the cosmos forever, providing evidence that challenged the prevailing philosophy of the time. It was discovered that other celestial bodies also have surface features and even moons of their own. Telescopes were not yet good enough to see many details, but imaginations ran wild.

WHAT'S ON THE SLIDE:
Galileo's sketches of the Moon and planets

EXTRAS:
The notion that other heavenly bodies were earthlike and not perfection challenged the Aristotilian view of nested crystalline spheres.

Slide 7

SCRIPT:
While our view of the universe expanded, science fiction and then Hollywood filled it with amazing places and creatures.
These stories have helped fire our imagination by giving shape to countless creatures from other planets and by helping us travel to distant worlds.

WHAT'S ON THE SLIDE:

Movie images:
Left: "Destination Moon" 1950
Center: Movie poster for "E.T. the Extra-Terrestrial" by John Alvin. © 1982 Universal Studios
Right: Movie poster for "Avatar" by James Cameron © 2009 20th Century Fox
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EXTRAS:
Science fiction films depicting extraterrestrial life go back more than a century. In 1902, the French film director, George Milies, created the classic silent movie short "A Trip to the Moon," which featured moon men encountered by astronauts from Earth. That film was featured in the Oscar winning 2011 film, Hugo.

Slide 8

SCRIPT:
In just the last few decades, telescopes and detectors have become sensitive enough to begin actual searches. Scientists faced a great challenge because planets around distant stars are not easy to detect.

WHAT'S ON THE SLIDE:
Photograph of the twin 10 meter Keck telescopes on Mauna Kea, Hawaii.
The image on the right is an artist's rendition of Kepler spacecraft. *Credit: NASA/Kepler mission/Wendy Stenzel*

Slide 9

SCRIPT:
There's a reason that it's hard to find planets. In addition to being small and far away, stars are a billion times brighter…

WHAT'S ON THE SLIDE:
Artist's rendering of a lighthouse with beacon shining.

Slide 10

SCRIPT:

…than a planet

[Click space bar]

…so planets are hidden in the glare.

WHAT'S ON THE SLIDE:

Artist's rendering of a lighthouse with beacon off. A small firefly is perched atop the lighthouse lamp.

Slide 11

SCRIPT:

Like this firefly.

WHAT'S ON THE SLIDE:

Artist's rendering of a lighthouse with beacon off. The firefly comes into full view.

Slide 12

SCRIPT:

By 1995, our technology was finally up to the task.
Swiss astronomers used new, more sensitive technology to make an historic discovery – the first planet to be found in orbit around another star. The star's name is 51 Pegasi (*peg-a-see*), and it is located in the fall constellation, Pegasus, the flying horse, 48 light years from Earth.

WHAT'S ON THE SLIDE:

Artist's rendering of an extrasolar planet. Black and white photograph of the scientists who made the discovery, Didier Queloz (*dee-dee-aye kway-lo*) and Michel Mayor.

EXTRAS:

The breakthrough came as a result of a more sensitive type of spectrograph which, as we will see, could sense very slight periodic motions in stars caused by the gravitational pull of encircling planets. Within a few months the American team of planet-hunters, Geoff Marcy and Paul Butler, would begin discovering many extrasolar planets using the same techniques.

* The first exoplanets were found in 1992 orbiting pulsars.

Slide 13

SCRIPT:
Again our view of the universe expanded. We were no longer the only star system we knew of. And from a single exoplanet…

WHAT'S ON THE SLIDE:
1 dot representing the first extrasolar planet discovered in 1995

Slide 14

SCRIPT:
…came many more discoveries. Some astronomers became "planet hunters" and pushed the limits of our technologies to find these distant worlds. Because of the methods in use at the time, most of these early discoveries were large gas giants.

WHAT'S ON THE SLIDE:
45 dots representing the 45 planets discovered by 2000
All numbers taken from NASA Exoplanet Archive as of Aug 1, 2013
http://exoplanetarchive.ipac.caltech.edu

Slide 15

SCRIPT:
NASA and other space agencies designed more sensitive instruments to detect these planets around other stars, called extrasolar planets, or just exoplanets.

WHAT'S ON THE SLIDE:
179 dots representing the 179 planets discovered by 2005

Slide 16

SCRIPT:
Within 15 years, astronomers were discovering stars with multiple planets. And the detection methods were allowing scientists to find smaller and smaller planets.

WHAT'S ON THE SLIDE:
534 planet dots

Slide 17

SCRIPT:
Currently, we have confirmed almost a thousand* exoplanets, with thousands more candidates awaiting confirmation.
How are we finding these elusive planets? There are many ways, but we'll discuss two of the most prolific here.

WHAT'S ON THE SLIDE:
You'll want to update this slide to update the current number of confirmed exoplanets. You'll see the bottom dots are grouped by 100. There are groups of 10 at the top left, and single dots on the top right. Copy and paste the blocks as needed to create a larger count. You can adjust the size of the circles as you might need more room.
This slide contains 882 dots. Find the current number of confirmed exoplanets here: http://planetquest.jpl.nasa.gov

Slide 18

SCRIPT:
There are many detection methods for finding planets. We'll talk more about the wobble and transit methods, the first two on this list in a minute. The last two listed here are also worth mentioning.
3) Some planets have been observed directly by blocking out the light of their parent star. But we saw what a challenge this could be with the lightening bug on the search light earlier.
4) Other planets have been observed thanks to particular alignments of the stars. Microlensing depends on a star with a planetary system passing between us and a background star. If the middle star has a planet, it will momentarily magnify the background star more than expected. The picture in the bottom right is a larger example of the microlensing phenomena with galaxy clusters
Now let's talk about how we're finding most of the exoplanets, with the first two methods.

WHAT'S ON THE SLIDE:
Top to bottom:

1) Artist's concept of red and blue shift from star wobble, ESO
2) Artist's concept of a planetary transit, ESO/L. Calçada
3) Star HR8799 is located at the small "x." The 3 planets shown are all more massive than Jupiter. NASA/JPL-Caltech/Palomar Observatory
4) Gravitational lensing of a background galaxy by a closer (orange) galaxy, ESA/Hubble & NASA

EXTRAS:
See an animation of gravitational microlensing here:
http://www.youtube.com/watch?v=w8RNn4MOem8

Slide 19

SCRIPT:
The first on that list of detection methods is the wobble method. This method measures the tug of planets on stars. On the top here we're watching from above as a very large planet's gravity tugs on a star, causing the star to wobble.
Here is how it works:
[Click space bar]
an unseen planet tugs the star back and forth…
[Click space bar]
light from the star shifts slightly to the red as the star moves away from the observer..
[Click space bar]
…and slightly to the blue as it moves toward the observer.
[Click space bar]
Astronomers can detect these shifts by very carefully observing the spectra (or colors) of the stars. This is also called the Doppler or Radial Velocity Method.

WHAT'S ON THE SLIDE:
Cartoon animation of how the "radial velocity" method of detecting planets using Doppler shift works. Use the arrow keys in "slide show mode" of PowerPoint to switch back and forth between the" blue shift" and the "red shift."

EXTRAS:
Because planets close to their stars complete a cycle around their stars faster and because massive planets tug harder on their stars and cause the biggest Doppler shifts, it is easiest to detect large and massive planets located close to their stars. Also, if a planet's orbit is tilted 90 degrees to our line of sight, no Doppler shift will be seen in the star's spectrum no matter how massive the planet.
See a hands-on demonstration of the effect here:
https://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=59

Slide 20

SCRIPT:
The Transit method has seen many hundreds of discoveries since the launch of the Kepler space telescope in 2009Transit detection depends on a star's light dimming slightly when a planet passes in front.
[Click space bar three times to show planet moving in front of star]
Kepler found planets using a specialized one-meter diameter telescope called a photometer to measure the small changes in brightness caused by these passing planets (or transits).
Imagine being able to detect the dimming in lighthouse beacon from a ladybug crossing its beam in Maine. From Los Angeles. This is how sensitive the instruments are.

WHAT'S ON THE SLIDE:
1. Cartoon animation of how the "transit method" works. Use the arrow keys in "slide show mode" of PowerPoint to show the planet moving back and forth across the star. You can use the arrow keys as a toggle to demonstrate the movement of the planet before moving on. Also, note the line on the graph shifting to show lower levels of light.
2. Artist's rendering of Kepler mission telescope.

Slide 21

SCRIPT:
Scientists expected other planetary systems to be like our own. Let me ask you all: Are there any other families that are just like your family? No? Well, scientists didn't find anything like our Solar System around other stars either.
This is a comparison of our Solar System with another planetary system that has a star similar to our Sun. On top, you'll see the orbits of the planets named Kepler-18b, c, and d. On the left side of that image is Mercury's orbit to scale. All of these large planets orbit closer to their parent star than any of the planets in our Solar System.

WHAT'S ON THE SLIDE:
Image comment: Top: the orbits of the three exoplanets orbiting Kepler-18 as compared to Mercury's solar orbit. Bottom: the relative sizes of the Kepler-18 and its known planets to the Sun and Earth
Image credits: UTA / McDonald Observatory / Tim Jones

Slide 22

SCRIPT:
Astronomers found incredible new planetary systems. We thought we knew quite a bit about how planets form, but planetary formation ideas have been revolutionized. We're finding planets in places theorized to be unlikely or impossible. Large gas giant planets orbiting their star in a matter of days or even hours, planets smaller than Earth, and more.
Note that in most cases, we don't see the planets directly.* We see their effect on the light from the parent stars. This slide and the next are artists' conceptions of planets that have been found.

WHAT'S ON THE SLIDE:
Top: Artist's conception of Kepler-10b, a scorched world, orbiting at a distance that's more than 20 times closer to its star than Mercury is to our own Sun. ***Credit:*** *NASA/Kepler Mission/Dana Berry*
Left: Artist's concept of the extrasolar planet HAT-P-7b ***Credit:*** *NASA, ESA, and G. Bacon (STScI)*
Right Credit: *Lucy West, space and science illustrator specializing in fine art space art; member of the International Association of Astronomical Artist, spokesperson and participant of Project Hermes, a Team Stellar/Google Lunar X Prize satellite project that will carry a collection of art mediums to the lunar surface in 2014.*

EXTRAS:
*Some planets *have* been imaged visually:
http://en.wikipedia.org/wiki/List_of_extrasolar_planets_directly_imaged

Slide 23

SCRIPT:
Astronomers have found multiple planets around stars, planets around more than one star, and even planets free-floating with no star at all.

WHAT'S ON THE SLIDE:
Top Left: At times, two or more planets pass in front of the star at once, as shown in this artist's conception of a simultaneous transit of three planets observed by NASA's Kepler spacecraft on Aug. 26, 2010. ***Credit:*** *NASA/Tim Pyle*
Right: Where the Sun Sets Twice - NASA's Kepler mission has discovered a world where two suns set over the horizon instead of just one. The planet, called Kepler-16b, is the most "Tatooine-like" planet yet found in our galaxy. Tatooine is the name of Luke Skywalker's home world in the science fiction saga "Star Wars." In this case, the planet it not thought to be habitable. It is a cold world, with a gaseous surface, but like Tatooine, it circles two stars. Image Credit: NASA/JPL-Caltech/R. Hurt
Bottom Left: An artist's impression of a free floating planet. Illustration: NASA/JPL-Caltech/R Hurt
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EXTRAS:
Prepare for your talk with updates on the latest discoveries. Find more information here: http://planetquest.jpl.nasa.gov/

Slide 24

SCRIPT:
Many of the new planets are not places where we expect that life could survive.
[Click space bar]
Some are gas giants without a stable surface. These large planets are the easiest to detect, so we often find those first.
[Click space bar]
Some get too hot or too cold to support life as we know it.
[Click space bar]
Many of them have highly elliptical orbits, or are too close to their parent stars. Why rule out so many great planets?

WHAT'S ON THE SLIDE:
Artist's rendering of planets too close in or too distant.

EXTRAS:
For a planet to have the right conditions for life, it has to be the right distance from its star. Also, a planet's orbit has to be fairly circular. Otherwise, at times, it would be carried too close or too far from its star for comfort.
Venus offers a good example of a runaway Greenhouse Effect. What free oxygen and water or water vapor that might have been present on Venus very early in its history have either escaped into space or combined with other substances in its soil and rock.
It is possible too for the moons of a gas giant planet to have solid surfaces and liquid water, but our technology still cannot detect that… yet.

Slide 25

SCRIPT:
Not just any planet can sustain life as we know it, though life is proving to be quite hardy.
It seems that everywhere we look on Earth has some sort of organism making that environment their home.
Life can survive in extreme pressures like the Pompeii Worm (top left), found in hot vents at the bottom of the ocean.\
Some organisms even thrive in boiling water. On the bottom left, the rushing fireberry likes it extremely hot.
The water bear on the right can survive even in the vacuum of space.
The one common trait that all these organisms share is that they need LIQUID WATER to survive.

WHAT'S ON THE SLIDE:
Examples of extreme organisms:
Top left: Pompeii worm, found deep at the bottom of the ocean near hydrothermal vents, in high-pressure, high temperature environments.

Bottom left: Rushing fireberry, has an optimum growth temperature of 100C, the boiling point of water. *Pyrococcus furiosus*
Right: Scanning electron micrograph of an adult water bear or tardigrade. These organisms can survive many extreme environments, including the vacuum of space.

EXTRAS:
Engage your audience with these cards about extremophiles:
https://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=480

Slide 26

SCRIPT:
Water. All life we know is dependent on water. So we are searching for planets that are in the "Habitable Zone" or "Goldilocks Zone", not too hot or too cold for water.
And we're finding them! Here, you can see that different stars have different habitable zones. This top system, Kepler-62 is around a small star, so the place where liquid water could exist is closer to the star than it is for our Sun, below.
Of course, even evidence of water does not mean that there is life on a planet, but it's the next step towards our search for life in the universe.

WHAT'S ON THE SLIDE:
This diagram compares the planets of the inner solar system to the five planets of Kepler-62, a star just two thirds the size of the Sun and only one fifth as bright. Two of the planets, Kepler-62f and Kepler-62e, lie in the star's habitable zone. The planets shown are artist's depictions. ***Credit:*** *NASA/Ames/JPL-Caltech*

EXTRAS:
Use this activity, What is the Habitable Zone?
https://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=394
Looking for more slides on the habitable zone and requirements for life? Find two additional presentations here.

The search for Earth-like planets: https://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=180
Drake Equation, probability of life in our galaxy:
https://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=478

Slide 27

SCRIPT:
We're finding that over half of all stars might host planets. That puts the estimated count at hundreds of billions of planets in our galaxy! One in 6 stars are thought to have Earth-sized planets. And we're finding some of those planets are in habitable zones.
Could there be some life out there looking back and wondering the same thing, "Are we alone?"

WHAT'S ON THE SLIDE:
This artist's illustration represents the variety of planets being detected by NASA's Kepler spacecraft. A new analysis has determined the frequencies of planets of all sizes, from Earths up to gas giants. Key findings include the fact that one in six stars hosts an Earth-sized planet in an orbit of 85 days or less, and that almost all Sun-like stars have a planetary system of some sort. (Hat tip to Robert Hurt for inspiring this illustration.) Credit: C. Pulliam & D. Aguilar (CfA)

EXTRAS:
If you want to talk about the likelihood of intelligent life in our galaxy, add slides from the Anyone Out There? PowerPoint here:
https://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=478

Slide 28

SCRIPT:
We don't have that evidence yet, so, we turn again to the poets and philosophers…
[read T.S. Eliot quatrain]
We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.

WHAT'S ON THE SLIDE:
1. Artist's rendition of an extrasolar planet.
2. A stanza from T.S. Eliot's, Four Quartets, Quartet No. 4: Little Gidding, written in 1942.

EXTRAS:
The award-winning PlanetQuest website contains all the information you (and your audience) need to know about the missions, the science, and the story behind the search for another Earth. Also, visit the gallery of multimedia interactives and keep up with the latest breaking news.
http://planetquest.jpl.nasa.gov

Slide 29

SCRIPT:
[This image is a placeholder that you may want to project while guests are leaving.]

WHAT'S ON THE SLIDE:
NASA vision statement and program credits.

Slide 30

END
Next slides are just extras if you want to further develop any part of the talk.

Slide 31

(Additional Slides)

Slide 32

SCRIPT:

You can even see some of the stars that have planets in the night sky… On clear, dark, moonless nights away from city lights, some stars with extrasolar planets can be seen with the naked eye. In this sky, you can see the stars and constellations visible to the naked eye from the northern hemisphere on a late spring or early summer evening.

WHAT'S ON THE SLIDE:

Artist's rendering of northern hemisphere night sky with major constellations.

Slide 33

SCRIPT:

…if you know where to look

Not far from the bright orange star Arcturus, in the constellation Bootes, the herdsman is the star tau Bootis. It is 49 light years away and has at least one planet. Below and to the right is the star Spica in the constellation Virgo and, within that constellation, is the star 70 virginis. It's 59 light years away and also has at least one planet.

WHAT'S ON THE SLIDE:

Artist's rendering of northern hemisphere night sky with major constellations. Inset windows showing how Earth's orbit compares to the orbits of the two discovered extrasolar planets.

EXTRAS:

Currently, about two dozen stars can be seen with the unaided eye. See the Distant Worlds Star Maps for a guide to which you'll see in the sky this month:
https://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=320

Slide 34

SCRIPT:

The Kepler mission is looking at hundreds of thousands of stars in this area of the sky. It's designed to study the structure and diversity of planetary systems using the transit method.

WHAT'S ON THE SLIDE:

Kepler Field of view superimposed on a photo of the summer evening sky.
Summer Triangle stars highlighted in yellow.
Credit: Carter Roberts

Slide 35

SCRIPT:
Just how far are these new planets?
[Click space bar]
If you wanted to radio home from the Moon, it would take one second for your words to reach Earth.
[Click space bar]
from Mars, it would take ten minutes.
[Click space bar]
and from the nearest extrasolar planet, it would take over four years for your words to reach Earth.
Even the nearest stars are very far away.

WHAT'S ON THE SLIDE:
1) Apollo 16, Astronaut John Young stepping onto the lunar surface on April 21, 1972;
2) Artist's rendering of the Mars Rover on the Red Planet; and
3) Artist's rendering of an extrasolar planet.

EXTRAS:
Most of the extrasolar planets we have found so far are quite close, astronomically speaking. Most of them are less than 1,000 light years away. That may seem far. But remember, the Milky Way Galaxy is 100,000 light years across, so these are only a tiny distance into the galaxy, as you will see in the next slide.

This is also an excellent place to show the interactives on the PlanetQuest website: http://planetquest.jpl.nasa.gov

Slide 36

SCRIPT:
But not far on a cosmic scale.
[Click space bar]
Imagine, if you shrunk our Solar System to a little larger than a quarter. Then, our Solar System would be this big.
[Click space bar]
Our Milky Way Galaxy would be the size of the United States,
[Click space bar]
and the nearest exoplanet around a distant star could be as close as the other side of Central Park
(Feel free to add another park or image in your area that indicates a distance of around 2 miles/4km.)

WHAT'S ON THE SLIDE:
1) A quarter vs. our solar system, 2) size of Milky Way Galaxy relative to the United States, and 3) photograph of central park in Manhattan, New York City © Jean-Christophe Benoist
EXTRAS:
The solar system is 7 billion miles across, or 11 light hours and the Milky Way Galaxy is about 100,000 light years across.